Mendocino Motor

Written By: Chris Connors

TOOLS:

- 3D printer (1)
  If you don't have access to a 3D printer, you can send the 3D part files out to a service like Shapeways or Ponoko and they'll print and mail them to you.
- Compass (1)
  for troubleshooting the polarity of the rotor coils
- Drill, handheld (1)
- Drill bit, 1/16" (1)
- Flux (1)
  if you're soldering leads to solar cells
- Laser cutter (1)
  to cut acrylic
- Sandpaper (1)
- Soldering iron and solder (1)

PARTS:

- Base connectors (4)
  in the zip file from Step 1
- Bearing plate connectors (2)
  in the zip file from Step 1
- Rotor block (1)
  in the zip file from Step 1
- Stator connectors (2)
  in the zip file from Step 1
- Front rotor bushing with bearing point (1)
  in the zip file from Step 1
- Rear rotor bushing (1)
  in the zip file from Step 1
- Pencils (3)
  or 1/4" wood dowels about 7-1/2" long
- Mirror or acrylic sheet (1)
  for the bearing plate
- Ring magnets (14)
  RadioShack #64-1888. Three packs of 5 are needed.
- Magnet wire (1)

RadioShack sells a 3-roll pack, #278-1345. The 30-gauge roll has enough wire for several Mendocino motors, plus you get 2 other gauges of wire you can use for other projects.

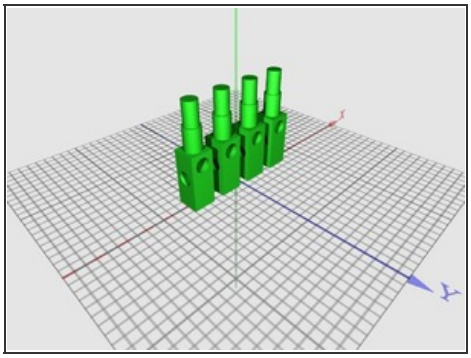
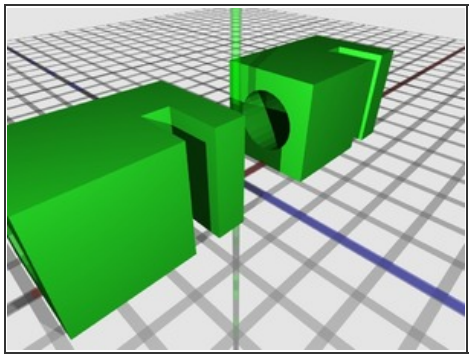
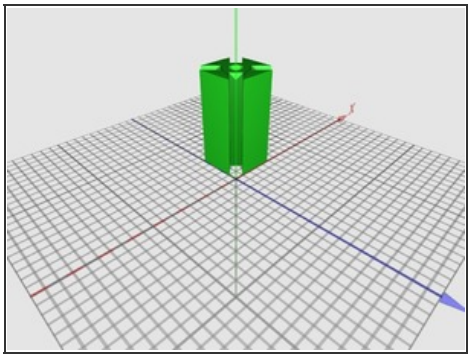
- Wooden paddle (1)
  A paint stirrer works well. Cutting 2 notches in each end helps keep the wire in place.
- Solar cells (4)
  Plastecs item #WB-18 (plastecs.com) measures 1.6"×0.8"; they're cheap but fragile, so get extras. Plastecs will make custom-sized cells, but get them with tab wires pre-soldered, because soldering them is tricky. Solarbotics #SCC2433B-MSE (solarbotics.com) measures 24mm×33mm; it's more expensive but it's encapsulated in epoxy for strength, has proper solder pads, and produces a higher voltage.
- Wood dowel (1)
  Certain pens of similar diameter and length work well also.
- Finishing nail (1)
- Tape (1)
  or similar
- Tape (1)
- Paper clip (1)
- Glue (1)
  such as barge cement, fabric glue, or other goopy all-purpose glue

SUMMARY

The Mendocino Motor floats in its own magnetic field and converts light into electricity and magnetism, which are then converted into the motion of the motor. It provides the satisfaction of creating an amazing bit of technology, and the opportunity to explore magnetism, electromagnetism, electric motors, solar power generation, and personal manufacturing.

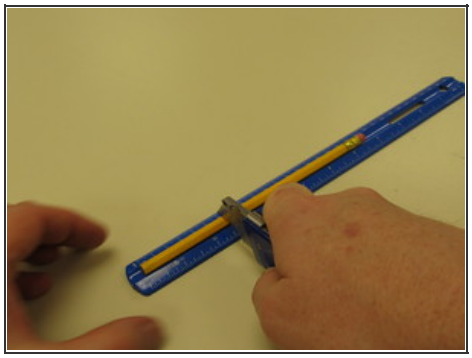
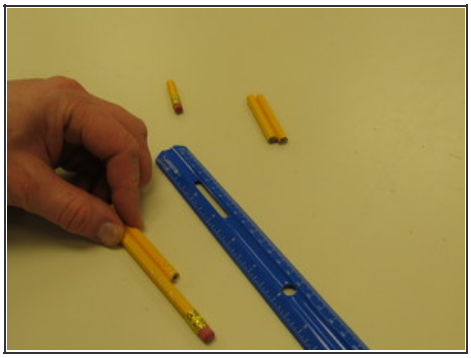
Build the base that holds the magnets and provides a bearing point for the motor. Then wind the motor coils, and solder them to the solar cells. When the motor is assembled, you'll balance it so it spins freely, and perform any troubleshooting to make it work properly.

Step 1 — Prepare the connectors and magnets.

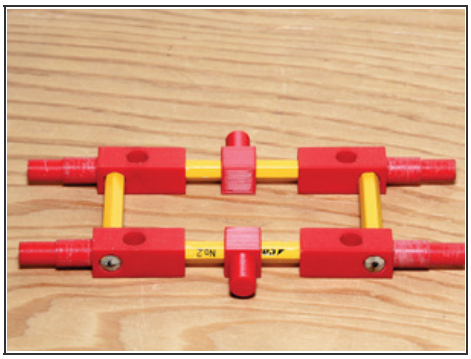
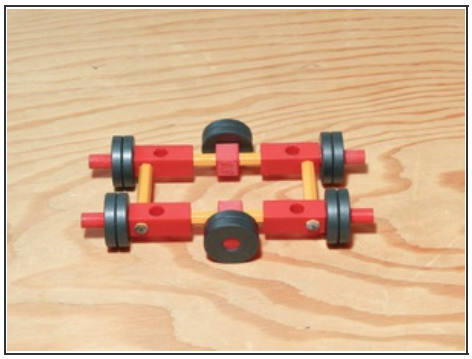
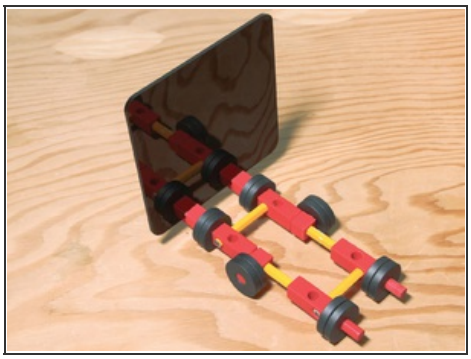
- In this assembly, you'll use 3D-printed parts. The part files can be found in this zip file; check back for updates as we continue to improve this project.
- Print four base connectors, two bearing plate connectors, one rotor block, one of each type of rotor bushing, and two stator connectors. Clean up any rough spots with sandpaper or a utility knife.
- Gather 8 ring magnets for the base, 4 for the stators, and 2 for the rotor. Use a compass to check the polarity of the magnets, and use a pencil to label them North and South.
- Remember, opposite poles attract, while like poles repel.
- If you have access to a laser cutter, cut the bearing plate from 1/8" acrylic (zip file is here). Two designs are provided.

Step 2 — Cut 2 pencils.

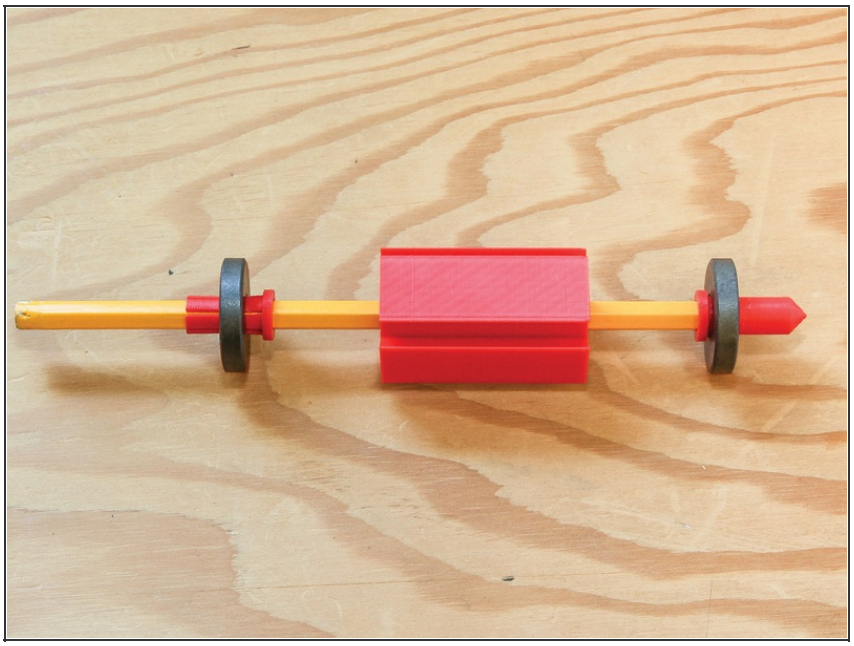
- Cut four 60mm segments from 2 of the pencils, using the utility knife.
- **TIP**: Roll the pencil beneath the knife until it cuts most of the way through. Then break the pencil.

Step 3 — Build the base.

- Slip 2 pencil segments into the side holes of the connectors, and 2 into the end holes, to make a frame that has 2 end connectors pointing forward, 2 pointing back, and 2 stator connectors pointing sideways.
- Slide a pair of magnets onto each connector, with South facing in toward the center of the base. If you're unsure which pole is South, just make sure the magnets near the mirror all face the same way magnetically, and the ones away from the mirror also all have the same pole facing inward, toward the center of the motor.
- Slip 2 magnets onto each stator connector, each pair pointing the same way magnetically. These will provide a stationary magnetic field around the rotor.
- Slip the bearing plate connectors onto one pair of end connectors. Slide the mirror or acrylic bearing plate into the slots to complete the base.

Step 4 — Build the rotor.



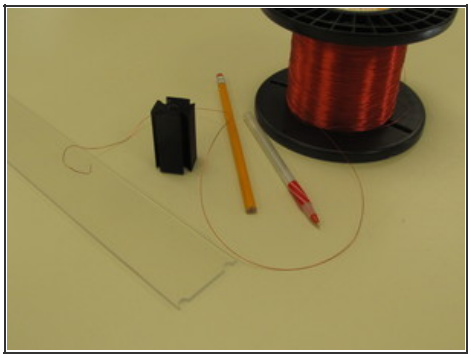
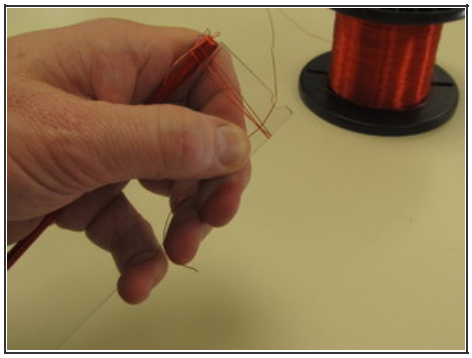
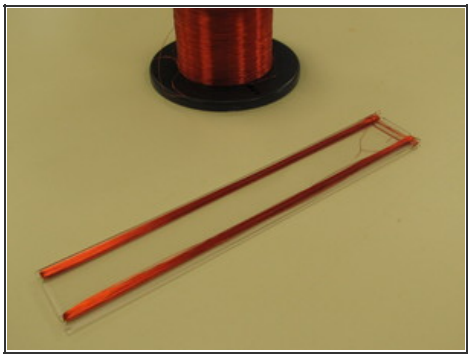
- Place the pencil into the rotor block, and slide the block to about the center.
- Push the front bushing onto one end of the pencil. It's tapered internally, so it won't go in all the way. Then slide one magnet onto that bushing.
- Push the rear bushing into a ring magnet, then slide it onto the rear of the rotor pencil. Slide the magnet further along the bushing until it "bites" down onto the pencil.

Step 5 — Test the magnetic levitation.

- Now you'll float the rotor so you can see how the magnetic levitation works. By floating the axle and rotor block without the other parts on it, you can test and adjust without worrying about breaking the solar cells.
- Test the rotor's balance by putting it into the field of the base magnets. Place the rotor so its bearing point is touching the bearing plate, and adjust the rotor magnets if necessary.
  - The front rotor magnet should centered directly above the frontmost base magnets.
  - The rear rotor magnet should be centered on the seams between the rear pairs of magnets.
- Now spin the rotor gently and let it turn. It's floating! (If not, check the polarity of the magnets and try again.)
- Make sure the rotor magnets don't wobble around on the pencil. If they can slip out of place, the magnetic field will force them away from their ideal position. The bushings are tapered externally, so snug the magnets up on the bushing if necessary.
- If the rotor climbs up the glass, the rotor magnets are too close to the mirror. If it jumps off the glass, they're too far away from it. Adjust

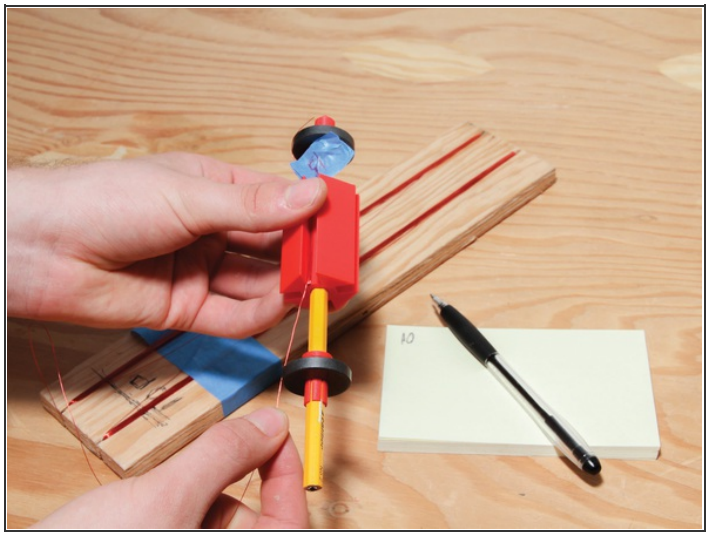
them until the rotor floats evenly.

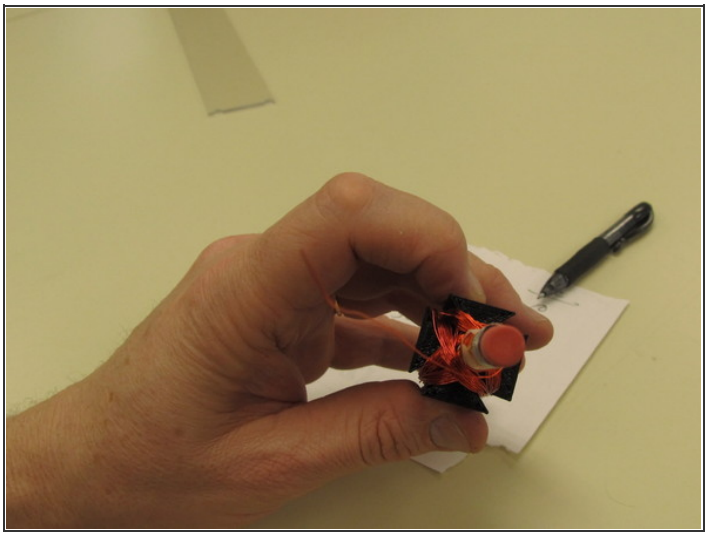
Step 6 — Measure out the magnet wire.

- Cut 2 notches in each end of the 1' wooden paddle.
- Measure out two 50' lengths of magnet wire. Wind the wire end-to-end onto the paddle, using one pair of notches to hold it. Count 25 turns; this will measure 50'. Break the wire and secure it with tape or wrap it around the notch.
- Do the same for the second 50' length. Now all your wire is measured and secured on the paddle. Loosen one end of one wire and put the paddle on the floor below you. It will unwind as you wrap the rotor.

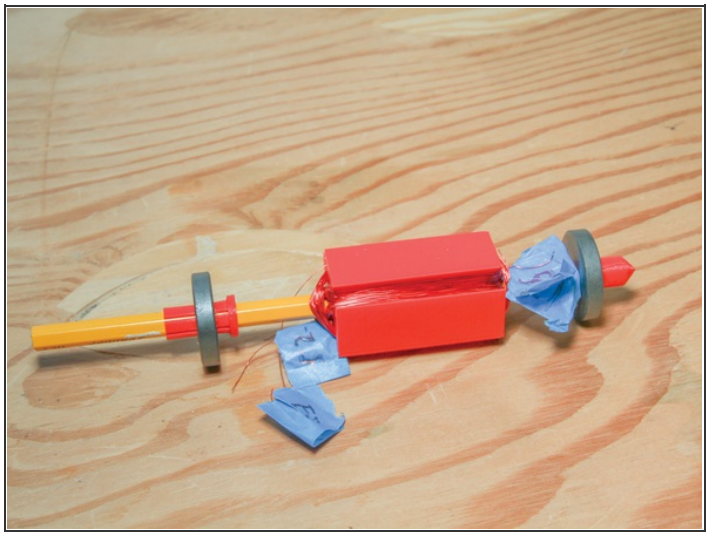
Step 7 — Wind the motor coils on the rotor.





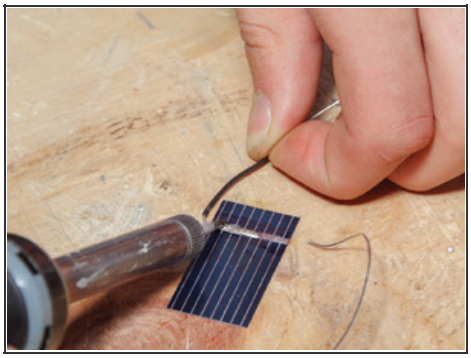
- Wrap the first magnet wire around one end of the pencil and label this end "S1" with a piece of paper and tape, meaning "start of wire 1."
- Hold the rotor upright in your right hand with one groove on top pointing toward you. With your left hand, bring the wire down into the groove toward you. Wind it under, into the opposite groove on the bottom, and back over into the top groove, remaining on the left side of the pencil. Wrap the wire around the rotor in this fashion until you've made 10 turns in the same grooves, on the left side of the pencil.
- Write down the number 10. If you lose count, your notes will help you lose just a few turns instead of unwrapping the whole thing and starting over.
- After the first set of 10, transfer the rotor to your left hand. Now make 10 turns of wire on the right side of the dowel, making sure it settles into the same grooves. When you have 10 more turns, write 20 to record this set. Repeat this process of alternating the side every 10 turns, always staying in the same grooves. There should be 100 turns of wire on the rotor when you're done. Label the end of this wire "E1" and secure it to the end of the pencil.
- Wind the second strand of magnet wire the same way, using the remaining 2 empty grooves and alternating sides every 10 turns. Start wire 2 on the opposite end of the pencil from where you started wire 1 and label it "S2." Your second wire should give the same number of turns as the first. Label its end "E2."

Step 8 — Test and trim the coil wires.



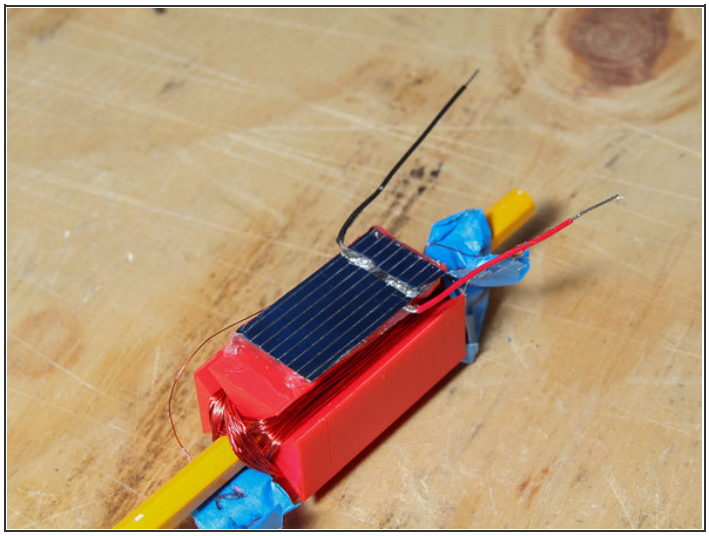
- Your rotor is now wrapped with 2 lengths of magnet wire, their 4 wire ends clearly labeled S1 and E1, S2 and E2.
- Carefully detach the wire ends from the pencil, keeping track of which is which.
- Remove 1/2" of insulation from each wire end using a patch of fine-grit sandpaper. This insulation is usually colored red, but sometimes it's green or even clear. You can also scrape it off with a knife, but be careful not to break the wire too close to the rotor.
- Use a multimeter set to "Continuity" to test the wires and confirm you've labeled them correctly. Then trim the wires to about 4" long and sand the ends again, so that you can solder them to the solar cells.

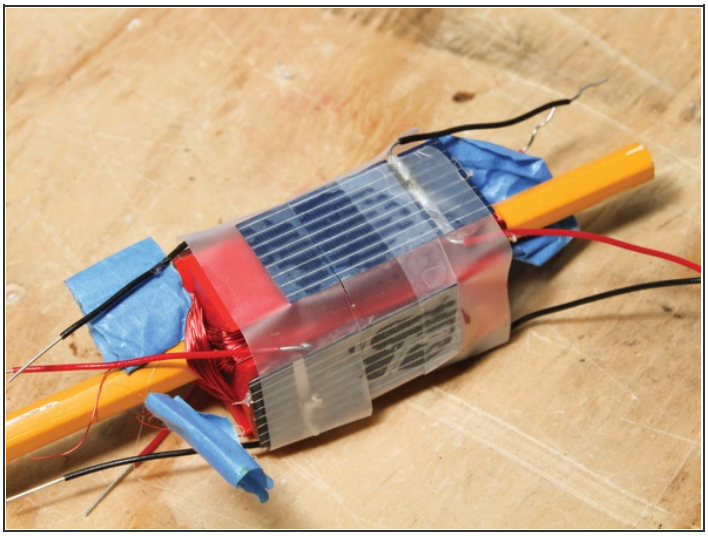
Step 9 — Solder leads to the solar cells (optional).

- If your cells already have leads or “tab wires” soldered to them, then skip this step.
- If you’re using Solarbotics cells, it’s easy: just solder wire leads to the positive and negative pads of each cell, the way you’d solder wire to a circuit board. You’re done!
- If you’re using Plastecs cells with no tab wires, this step is somewhat difficult. The cells are heat-sensitive and shatter easily, so it’s important to solder the joint quickly. Pre-tin the cell and the wire lead, then touch them together and briefly reheat to solder the 2. If that doesn't work well for you, try using flux.
- Apply flux to the cell where you intend to solder it, and possibly dip the end of your lead in flux as well. The positive output is the entire back side of the cell, and the negative output is the wide stripe across the front of the cell. Flux helps the solder to bond to the metal faster, reducing the risk of breaking or overheating the cell.
- Even if you’re experienced with a soldering iron, your solder joints will likely not look pretty. There may be some flux residue left, but it won’t harm the cell’s performance much. Just make sure the solder joint is firm.
- Also, if you use solid-core wire, make sure both leads exit the cell in the same direction, running lengthwise relative to the cell. They’re hard to bend later without damaging the cell.

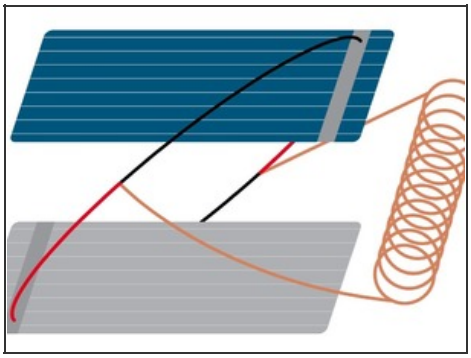
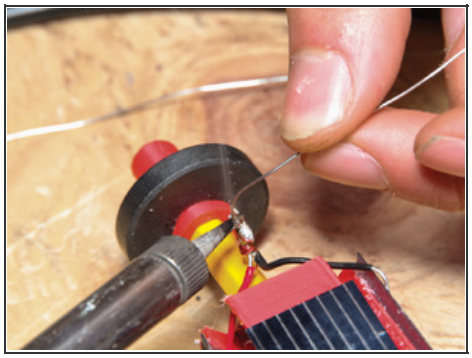
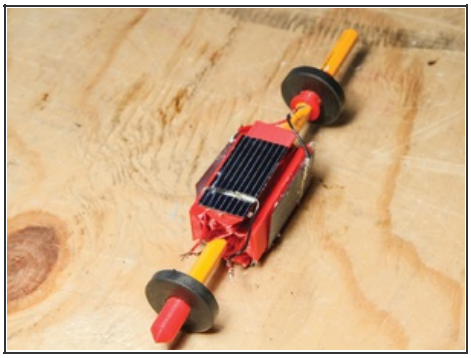
Step 10 — Attach the solar cells.





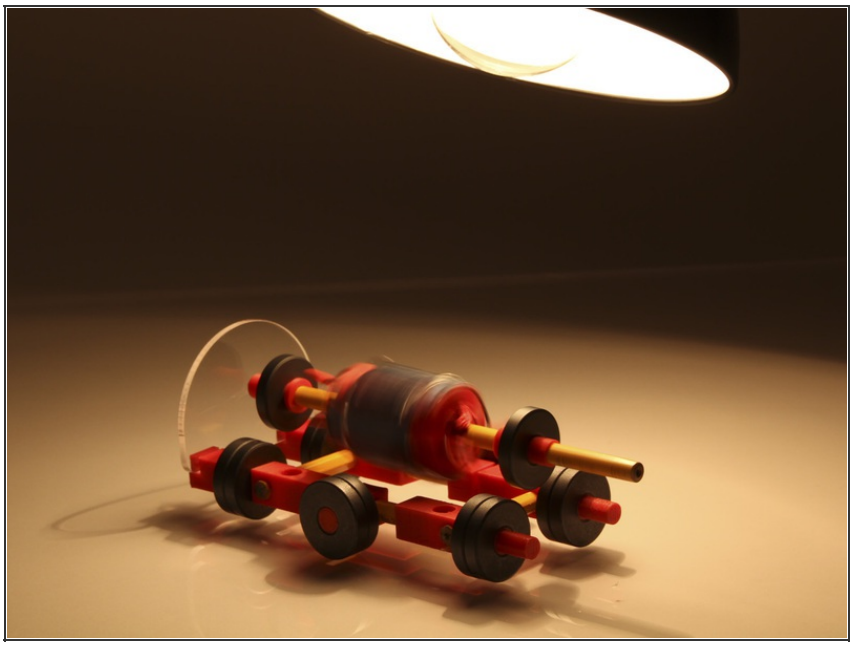
- Each solar cell has 2 leads: one coming from the front and one from the back. Arrange the cells on the rotor block so that the front lead can easily reach the back lead of the cell on the opposite side of the block.
- Put a bead of adhesive on one face of the block. Barge cement, fabric glue, or other goopy all-purpose glue is ideal. You want a glue that is liquid when applied, doesn't change shape much, and is easy to spread.
- Stick the first cell to the block and tape it in place with 100mm of clear adhesive tape, starting on the bare face of the block adjacent to the cell, wrapping over the cell, attaching to the next bare face.
- If you leave the tape in place, it will serve as a protective cover for the solar cells. Later, you can also adjust the center of balance by adding solder or another non-ferrous material between the tape and the coil.
- Glue the second cell to the face opposite the first cell, ensuring that its positive (back) lead is near the negative (front) lead of the first cell, and vice versa.
- Repeat this process to attach the remaining 2 solar cells, always making sure that the tabs from adjacent cells do not touch each other.

Step 11 — Connect the solar cells and coils.

- Bend all the leads so that each negative (front) lead is mechanically connected to the positive (back) lead of the cell on the opposite side of the block.
- Solder all 4 connections, making sure you're connecting the cells on opposite sides of the block (not cells that are next to each other).
- Connect each of the coil windings into the circuit as shown in the diagram. Each coil is driven by its own pair of solar cells. Connect the first coil to one pair of cells by soldering the coil leads into the (+/–) connections you just made between those cells. Repeat with the second coil and second pair of cells.

Step 12 — Test the motor in the light.



- Place your fully assembled and balanced motor in bright light to see it work. The motor turns best in sunlight. Halogen and incandescent lights work very well also. Fluorescent light usually doesn't work well.
- Your motor should self-start if it's balanced properly and the magnets are placed correctly with no wobble. Sometimes you can coax a motor into running by moving the light rhythmically and getting it to rotate. You can also gently spin the motor to get it started. Be careful not to spin it too fast, or it may jump out of the magnetic field and break.
- The stator magnets provide a stationary force that the motor turns against. Your motor may turn without them, but the fastest-running motors I've seen used stators.
- For troubleshooting tips, see the next step.

Step 13 — Troubleshoot the motor.

- **Balance** is a common problem. Remove the stator magnets, then turn the rotor ½ turn and let go (don't spin it). If it rotates back to its original position instead of rotating forward, add weight to the highest part of the circle. Try brass or solder. Don't add nails or other steel weights, because they're made with iron, and are magnetic.
- **Magnets** must be firmly and accurately placed. If they can wobble out of position, they will.
  - If needed, neatly tape the base magnets to keep them aligned straight up and down. Make sure they're all oriented with South poles facing inward, or at least all facing consistently.
  - If needed, add tape to the bushings to keep the rotor magnets from wobbling. Again, the front rotor magnet is centered over the frontmost base magnet, and the rear rotor magnet is centered over the rear pair of base magnets.
- **Solar cells** — Make sure you have continuity between each pair of opposite cells, and not between adjacent cells. If your continuity is off, you may have to rewire the connections. If a cell is connected to an adjacent cell, then reconnect it to the opposite cell.
- **Reversed polarity** — If everything above is correct, and the rotor still just wobbles back and forth in the light, try this technique.
  - Neatly cut one pair of coil wires from one pair of cells. Re-sand the ends of the wires, then solder them onto the cell leads opposite from the leads they were on originally. This changes the direction of the electricity flowing through that particular coil. If your problem was reversed polarity, this should fix it.

Step 14 — Show off your Mendocino Motor!

- When I show the Mendocino Motor to electrical engineers or physics teachers, I have fun hearing them think out loud about how it works.
- Place your Mendocino Motor in a sunny window, and you'll see it start up when the sunlight is bright enough, and slow to a stop when the day fades. Put it on your desk and watch it turn in the light of your lamp as you work. Try different types of bulbs for differing results in speed.
- The Mendocino Motor has little torque or turning power, so it's a challenge to harness its motion for other uses. You could fashion a fan on the rotor axle to move some air. (Stick more magnets onto the stators to increase torque.) What other uses can you think of?

This project first appeared in MAKE Volume 31, page 64.

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